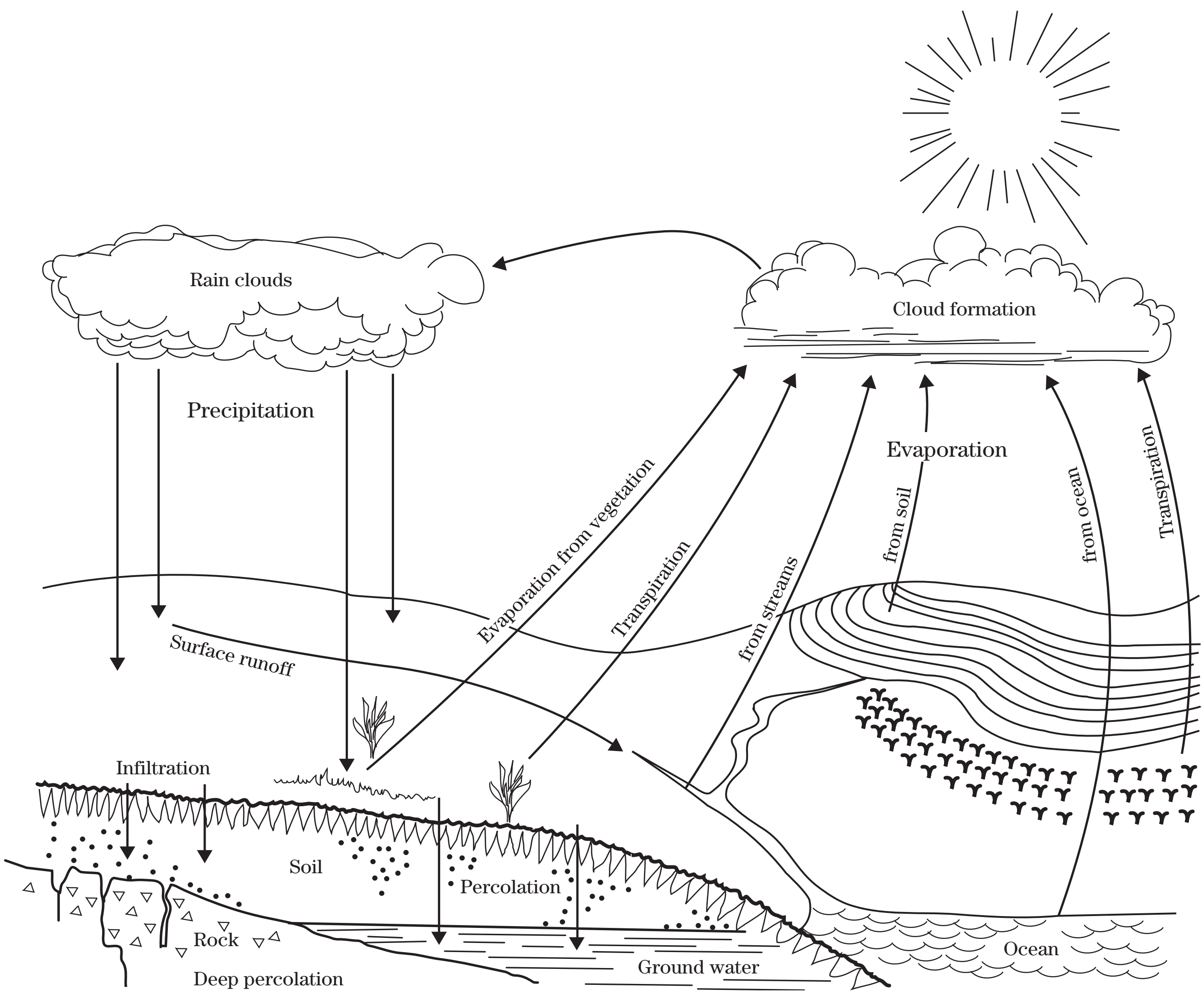
United States
Department of
Agriculture

Natural
Resources
Conservation
Service

Part 630 Hydrology
National Engineering Handbook

Chapter 9 Hydrologic Soil-Cover Complexes



Issued July 2004

Acknowledgments

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Chapter 9 Hydrologic Soil-Cover Complexes

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630.0900 General

A combination of a hydrologic soil group (soil) and a land use and treatment class (cover) is a hydrologic soil-cover complex. This chapter gives tables and graphs of runoff curve numbers (CNs) assigned to such complexes. This CN indicates the runoff potential of a complex during periods when the soil is not frozen. A higher CN indicates a higher runoff potential and specifies which runoff curve of appendix A or figure 10–2 in National Engineering Handbook, part 630 (NEH 630), chapter 10, is to be used in estimating runoff for the complex. Applications and further description of CNs are given in NEH 630, chapters 10 and 12.

630.0901 Determinations of complexes and curve numbers

(a) Agricultural land

Complexes and assigned CNs for combinations of soil groups of NEH 630, chapter 7 and land use and treatment classes of NEH 630, chapter 8 are given in table 9–1. Also given are some complexes that make applications of the table more direct. Impervious and water surfaces, which are not listed, are always assigned a CN of 98.

(1) Assignment of CNs to complexes

Table 9–1 was developed as follows:

- The data literature was searched for watersheds in single complexes (one soil group and one cover); watersheds were found for most of the listed complexes.
- An average CN for each watershed was obtained using rainfall-runoff data for storms producing the annual floods. The watersheds were generally less than 1 square mile in size, the number of watersheds for a complex varied, and the storms were of 1 day or less duration.
- The CNs of watersheds in the same complex were averaged and all CNs for a cover were plotted. A curve for each cover was drawn with greater weight given to CNs based on data from more than one watershed, and each curve was extended as far as necessary to provide CNs for ungaged complexes. All but the last three lines of CN entries in table 9–1 are taken from these curves.
- For the complexes in the last three lines of table 9–1, the proportions of different covers were estimated and the weighted CNs computed from previously derived CNs.

Table 9–1 has not been significantly changed since its construction in 1954 although CNs for crop residue cover treatment has been added. Supplementary tables for special regions have been developed and are shown later in this chapter.

(2) Use of table 9–1

Chapters 7 and 8 of NEH 630 describe how soils and covers of watersheds or other land areas are classified in the field. After the classification is completed, CNs are read from table 9–1 and applied as described in chapter 10. Because the principal use of CNs is for estimating runoff from rainfall, the examples of applications are given in chapter 10.

Table 9–1 Runoff curve numbers for agricultural lands [1/]

Cover description			CN for hydrologic soil group			
cover type	treatment [2/]	hydrologic condition [3/]	A	B	C	D
Fallow	Bare Soil	---	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C & T)	Poor	66	74	80	82
		Good	62	71	78	81
	C & T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C & T	Poor	61	72	79	82
		Good	59	70	78	81
	C & T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C & T	Poor	63	73	80	83
		Good	51	67	76	80

See footnotes at end of table.

Table 9–1 Runoff curve numbers for agricultural lands [1/] — Continued

Cover description: cover type	treatment [2/]	hydrologic condition [3/]	CN for hydrologic soil group: A	B	C	D
Pasture, grassland, or range-continuous forage for grazing [4/]		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
Meadow-continuous grass, protected from grazing and generally mowed for hay		Good	30	58	71	78
Brush-brush-forbs-grass mixture with brush the major element [5/]		Poor	48	67	77	83
		Fair	35	56	70	77
		Good	30 [6/]	48	65	73
Woods-grass combination (orchard or tree farm) [7/]		Poor	57	73	82	86
		Fair	43	65	76	82
		Good	32	58	72	79
Woods [8/]		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	30	55	70	77
Farmstead--buildings, lanes, driveways, and surrounding lots		---	59	74	82	86
Roads (including right-of-way):						
Dirt		---	72	82	87	89
Gravel		---	76	85	89	91

1/ Average runoff condition, and I_a=0.2s.

2/ Crop residue cover applies only if residue is on at least 5 percent of the surface throughout the year.

3/ Hydrologic condition is based on combinations of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥20%), and (e) degree of surface toughness.
Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better then average infiltration and tend to decrease runoff.
For conservation tillage poor hydrologic condition, 5 to 20 percent of the surface is covered with residue (less than 750 pounds per acre for row crops or 300 pounds per acre for small grain).
For conservation tillage good hydrologic condition, more than 20 percent of the surface is covered with residue (greater than 750 pounds per acre for row crops or 300 pounds per acre for small grain).

4/ Poor: < 50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.

5/ Poor: < 50% ground cover.
Fair: 50 to 75% ground cover.
Good: > 75% ground cover.

6/ If actual curve number is less than 30, use CN = 30 for runoff computation.

7/ CNs shown were computed for areas with 50 percent woods and 50 percent grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.

8/ Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed, but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

(b) National and commercial forest: forest-range

(1) Forest-range in Western United States

In the forest-range regions of the Western United States, soil group, cover type, and cover density are the principal factors used in estimating CNs. Figures 9–1 and 9–2 show the relationships between these factors and CNs for soil-cover complexes used to date. The figures are based on information in table 2–1, part 2, of the USDA Forest Service's Handbook on Methods of Hydrologic Analysis (USDA 1959b). The amount of litter is taken into account when estimating the density of cover.

Present hydrologic conditions are determined from existing surveys or by reconnaissance, and future conditions from the estimate of cover and density changes resulting from proper use and treatment. Table 9–2 lists CNs for arid and semiarid rangelands. It is used like table 9–1.

Figure 9–1 Estimating runoff curve numbers of forest-range complexes in Western United States: herbaceous and oak-aspen complexes

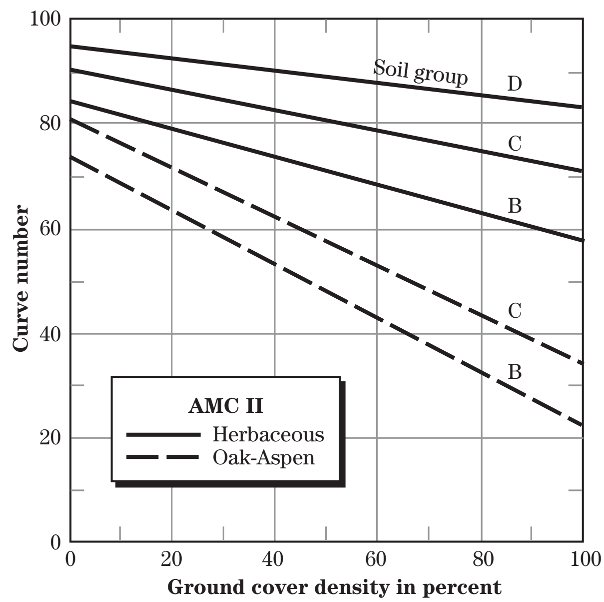


Figure 9–2 Estimating runoff curve numbers of forest-range complexes in Western United States: juniper-grass and sage-grass complexes

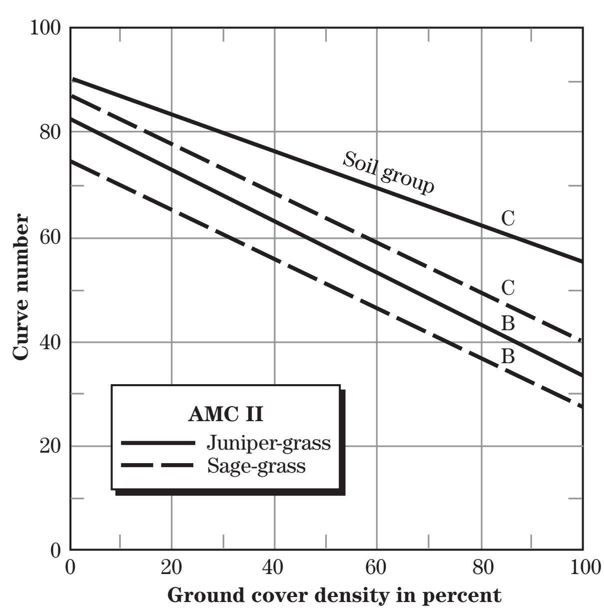


Table 9–2 Runoff curve numbers for arid and semiarid rangelands 1/

Cover description: cover type	Cover description: hydrologic condition 2/	Hydrologic soil group: A 3/	B	C	D
Herbaceous—mixture of grass, weeds and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sage-grass—sage with an understory of grass	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, paloverde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1/ Average runoff condition, and I_a = 0.2s. For range in humid regions, use table 9–1.

2/ Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: >70% ground cover.

3/ Curve numbers for group A have been developed only for desert shrub.

(2) Supplementary tables of CNs

Tables 9–3 and 9–4 are supplements to table 9–1 and are used in the same way. Table 9–3 gives CNs for selected covers in Puerto Rico. The CNs were obtained using a relation between storm and annual data and the annual rainfall-runoff data for experimental plots at Mayaguez, Puerto Rico.

Table 9–4 gives CNs for sugarcane complexes in Hawaii. The CNs are tentative estimates now undergoing study.

Table 9–3 Runoff curve numbers for hydrologic soil-cover complexes in Puerto Rico [1/]

Cover description cover type and hydrologic condition	CN for hydrologic soil group A	 B	 C	 D
Fallow	77	86	91	93
Grass (bunchgrass or poor stand of sod)	51	70	80	84
Coffee (no ground cover, no terraces)	48	68	79	83
(with ground cover and terraces)	22	52	68	75
Minor crops (garden or truck crops)	45	66	77	83
Tropical kudzu	19	50	67	74
Sugarcane: (trash burned, straight-row)	43	65	77	82
(trash mulch, straight-row)	45	66	77	83
(in holes, on contour)	24	53	69	76
(in furrows, on contour)	32	58	72	79

1/ Average runoff condition, and $I_a = 0.2S$.

Table 9–4 Runoff curve numbers; tentative estimates for sugarcane hydrologic soil-cover complexes in Hawaii [1/]

Cover and treatment [2/]	------- Hydrologic soil group -------			
	A	B	C	D
Sugarcane:				
Limited cover, straight row	67	78	85	89
Partial cover, straight row	49	69	79	84
Complete cover, straight row	39	61	74	80
Limited cover, contoured	65	75	82	86
Partial cover, contoured	25	59	75	83
Complete cover, contoured	6	35	70	79

1/ Average runoff condition and $I_a = 0.2S$.

2/ Degrees of cover:
Limited cover—Cane newly planted, or ratooned cane with a limited root system; canopy over less than half the field area.
Partial cover—Cane in the transition period between limited and complete cover; canopy over half to nearly the entire field area.
Complete cover—Cane from the stage of growth when full canopy is provided to the stage at harvest.
Straight-row planting is up and down hill or cross-slope on slopes greater than 2 percent.
Contoured planting is the usual contouring or cross-slope planting on slopes less than 2 percent.

(c) Urban and residential land

Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system, should be considered in computing CNs for urban areas (Rawls et al., 1981). For example, do the impervious areas connect directly to the drainage system, or do they outlet onto lawns or other pervious areas where infiltration can occur?

The urban and residential CNs given in table 9–5 were developed for typical land use relationships based on specific assumed percentages of impervious area. These CN values were developed on the assumptions that

- pervious urban areas are equivalent to pasture in good hydrologic condition,
- impervious areas have a CN of 98 and are directly connected to the drainage system, and
- the cover types listed have assumed percentages of impervious area as shown in table 9–5.

Sheet flow is flow over plane surfaces that usually occurs in the headwater of streams immediately after the rainfall's impact. Sheet flow has very shallow flow depths of 0.05 to 0.1 foot, with laminar flow characteristics of parallel or nearly parallel flowlines and a maximum flow length of 100 feet.

Shallow concentrated flow occurs downstream from sheet flow and upstream from flow in a defined channel. In shallow concentrated flow, the water flows in nonparallel flow paths, and flow depths range from 0.1 foot to as much as 0.5 foot.

In concentrated flow the water follows definite channels that are a discernable feature on the ground surface. See NEH 630, Chapter 15, Time of Concentration, for more information on these flow types.

(1) Connected impervious areas

An impervious area is considered connected if runoff from it flows directly into the drainage system. It is also considered connected if runoff from it occurs as shallow concentrated flow that runs over a pervious area and then into a drainage system.

If all of the impervious area is directly connected to the drainage system, but the impervious area percentages in table 9–5 or the pervious land use assumptions are not applicable, use equation 9–1 or figure 9–3 to compute a composite CN.

$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right)\left(98 - CN_p\right) \qquad [9\text{–}1]$$

where:
CN_c = composite runoff curve number
CN_p = pervious runoff curve number
P_{imp} = percent imperviousness.

Figure 9–3 Composite CN with connected impervious area

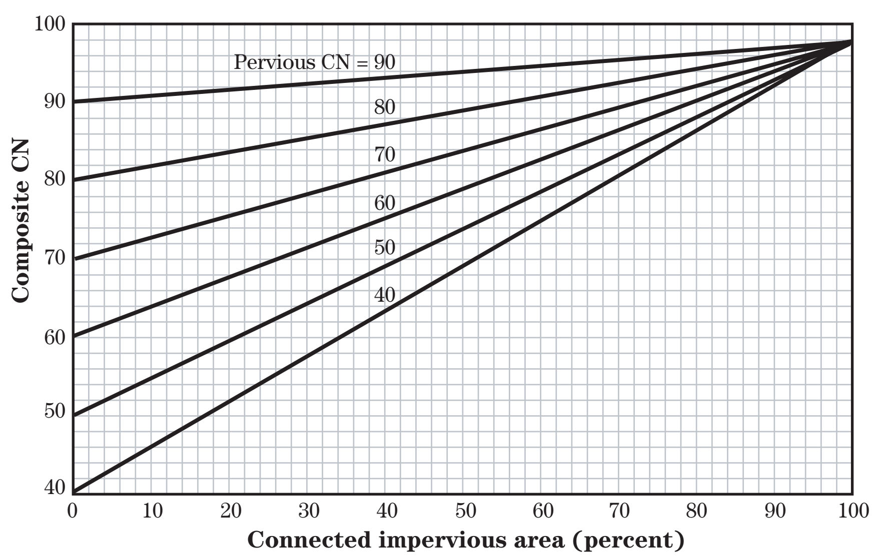


Table 9–5 Runoff curve numbers for urban areas [1/]

Cover description cover type and hydrologic condition	Average percent impervious area [2/]	- - CN for hydrologic soil group - - A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3/]					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4/]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94

1/ Average runoff condition, and $I_a = 0.2S$.

2/ The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

3/ CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space type.

4/ Composite CNs for natural desert landscaping should be computed using figures 9–3 or 9–4 based on the impervious area percentage (CN=98) and the pervious area CN. The pervious area CNs are assumed equivalent to desert shrub in poor hydrologic condition.

Example 9–1 Calculation of composite urban residential CN with different percentage of impervious area than that assumed in table 9–5

Given: Table 9–5 gives a CN of 70 for a ½-acre lot in HSG B with an assumed impervious area of 25 percent. The pervious area CN is 61.

Problem: Find the CN to be used if the lot has 20 percent impervious area.

Solution: **Method 1**—Solve equation 9–1 with CN_p, the pervious runoff curve number, equal to 61 and P_{imp}, the percent imperviousness, equal to 20:

$$CN_c = 61 + \left(\frac{20}{100}\right)(98 - 61)$$

$$CN_c = 61 + (.20)(37)$$

$$CN_c = 61 + 7.4$$

$$CN_c = 68.4 \text{ round to } 68$$

The CN difference between 70 in table 9–5 and 68 reflects the difference in percent impervious area.

Method 2—Enter figure 9–3 with the percentage of impervious area equal to 20 and move up to a point a little above the curve representing a pervious curve number of 60 to find the point for a pervious CN of 61. Read the Composite CN of 68 on the left axis.

The CN difference between 70 in table 9–5 and 68 reflects the difference in percent impervious area.

Example 9–2 Calculation of a composite urban residential CN with different CN for the pervious area than that assumed in table 9–5

Given: Table 9–5 gives a CN of 70 for a ½-acre lot in HSG B with an assumed impervious area of 25 percent. The pervious area CN is 61.

Problem: Find the CN to be used if the lot's pervious area has a CN of 69, indicating fair condition instead of good condition.

Solution: **Method 1—**Solve equation 9–1 with CN_p, the pervious runoff curve number, equal to 69 and P_{imp}, the percent imperviousness, equal to 25:

$$CN_c = 69 + \left(\frac{25}{100}\right)(98 - 69)$$

$$CN_c = 69 + (.25)(29)$$

$$CN_c = 69 + 7.25$$

$$CN_c = 76.25 \text{ round to } 76$$

The CN difference between 70 in table 9–5 and 76 reflects the difference in the pervious area CN.

Method 2—Enter figure 9–3 with the percentage of impervious area equal to 25 and move up to a point a little below the curve representing a pervious curve number of 70 to find the point for a pervious CN of 69. Read the Composite CN of 76 on the left axis.

The CN difference between 70 in table 9–5 and 76 reflects the difference in the pervious area CN.

(2) Unconnected impervious areas

If runoff from impervious areas occurs over a pervious area as sheet flow prior to entering the drainage system, the impervious area is unconnected. To determine CN when all or part of the impervious area is not directly connected to the drainage system:

- use equation 9–2 or figure 9–4 if the total impervious area is less than 30 percent of the total area or
- use equation 9–1 or figure 9–3 if the total impervious area is equal to or greater than 30 percent of the total area, because the absorptive capacity of the remaining pervious areas will not significantly affect runoff.

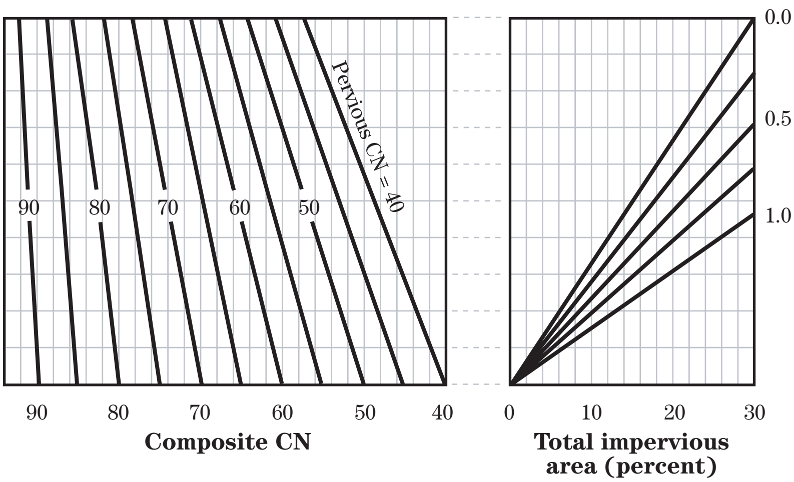
$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right)\left(98 - CN_p\right)\left(1 - .05R\right) \quad [9–2]$$

where:

CN_c = composite runoff curve number
CN_p = pervious runoff curve number
P_{imp} = percent imperviousness
R = ratio of unconnected impervious area to total impervious area

When impervious area is less than 30 percent, obtain the composite CN by entering the right half of figure 9–4 with the percentage of total impervious area and the ratio of total unconnected impervious area to total impervious area. Then move left to the appropriate pervious CN and read down to find the composite CN.

Figure 9–4 Composite CN with unconnected impervious areas and total impervious area less than 30%



Example 9–3 Determine the composite CN with unconnected impervious areas and total impervious area less than 30%

Given: A ½-acre lot in HSG B has an assumed impervious area of 20 percent, 75 percent of which is unconnected. The pervious area CN is 61.

Problem: Find the CN to be used for the lot.

Solution: **Method 1—**Solve equation 9–2 with CN_p, the pervious runoff curve number, equal to 61; P_{imp}, the percent impervious area, equal to 20; and R, the ratio of unconnected impervious area to total impervious area, equal to 0.75:

$$CN_c = 61 + \left(\frac{20}{100}\right)(98-61)\left(1-0.5(0.75)\right)$$
$$CN_c = 61 + (.20)(37)(1-0.375)$$
$$CN_c = 61 + (.20)(37)(0.625)$$
$$CN_c = 61 + 4.62$$
$$CN_c = 65.62 \text{ round to } 66$$

Method 2—Enter the right half of figure 9–4 with the percentage of impervious area equal to 20 and move up to the 0.75 line for the ratio of unconnected impervious area to total impervious area. Then move to the left part of the figure, left to the appropriate pervious CN 61, and read down to find the composite CN 66.

The CN considering all the impervious areas to be connected as in example 9–1 is 68. Example 9–3 shows that if 75 percent of the impervious area is unconnected, the CN is reduced to 66.

630.0902 References

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